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NADI PARIKSHA: A NOVEL MACHINE LEARNING BASED WRIST PULSE ANALYSIS THROUGH PULSE AUSCULTATION SYSTEM USING K-NN CLASSIFIER

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ABSTRACT

The Nadi pariksha technique, which dates to ancient Ayurveda, is a fabulous approach for detecting imbalances in the human body. The pulse, or Nadi (old term), is a vital movement of energy, or life, that moves through the delicate medium of the human body, allowing the physician to feel and understand the blood flow into and out of the heart. It is a traditional method for identifying physical, mental, and emotional imbalances in the body, as well as diseases. A technique for measuring the pressure in pulses like this is useful for disease detection. For any disease diagnosis, however, Nadi pariksha requires experts with vast experience and pulse reading skills. In this paper, an ultrasound microphone sensor is used to identify three Ayurveda doshas, namely, Vata, Pitta, and Kapha, from a collected Nadi signal at a single place. Different statistical features are retrieved for each signal and categorized using the K-NN classifier to identify these three doshas. The proposed work has been tested and validated in a clinical setting with several patients, and we observed that this method results in a higher identification rate for all three doshas.

Keywords: Earthquake, Accelerometer, Arduino UNO, Alarm, GSM, Brain wave, Mind wave mobile, physically disabled, GPS.

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1. INTRODUCTION

Ayurveda literally means "Science of Life," with *Ayur* meaning "life" and *Veda* meaning "science." *Ayurveda*, an ancient medicinal system, has been greatly expanded and improved in India for thousands of years. The relationship between the body, mind, and spirit, according to this ancient technique, helps to determine the human body's fitness and health. The healthiest state is when the body, mind, and soul are all in tune with the universe. Our health is said to be

in poor condition if our body, mind, and soul are at odds with the cosmos. Genetics, birth defects, age, injuries, emotions, seasonal changes, and climate are all elements that contribute to a state of imbalance in the human body, mind, and spirit.

A living creature, according to *Ayurveda*, is made up of five components in the universe: Space, Air, Fire, Water, and Earth. Earth represents smell, Water represents taste, Fire represents sight, Air represents touch, and Space represents hearing. These five elements contribute to manage the human body through three forces or energies known as *tridoshas* [7]: *Vata*, *Pitta*, and *Kapha*. The first, middle, and third fingers of the subject's hand are used to apply gentle pressure to the radial pulse of the wrist near the radial fossa to examine the *tridoshas*. Mentally, a *Vaidya* or an adept physician observes the acute quality of the pulses. To read the pulse accurately and discover the imbalance in the *tridoshas*, it takes a lot of concentration and knowledge. The index, middle, and third fingertips are used to observe the *tridoshas Vata*, Piita, and *Kapha*, respectively. Fig. 1 shows the exact position for finding and reading the pulse from the wrist.

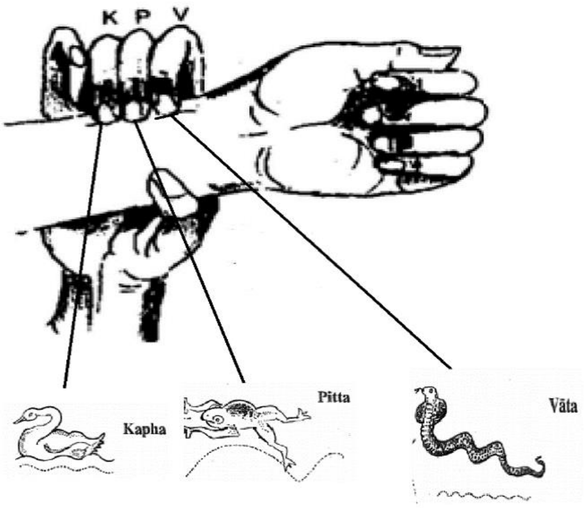

Figure 1 Position and Nature of Pulses

The most essential of the three doshas, *Vata*, is made up of air and space. *Vata* is the most important dosha in the human body, as it governs the functions of the other two doshas, as well as the tissues and waste products. Essentially, *Vata* supports all metabolisms in the human body and regulates all physical and mental processes. *Vata* aids in the transmission of all sensory impulses to the brain from numerous sense organs. It also regulates all bodily eliminations such as sperm, faeces, urine, and perspiration [4]. *Pitta* is a combination of water and fire, and it is present wherever there is a transformation. It regulates a variety of functions, including food digestion, conversion, and a few others. *Pitta* is responsible for thermogenesis, as well as eyesight, appetite, and skin tone. *Pitta* is primarily responsible for bravery and courage. The heaviest of the three doshas, *Kapha*, is made up of water and earth. It provides moisture and lubrication to reduce excessive friction in the human body, strength to complete diverse physical tasks, and stability to provide the body and mind the required foundation. It is in charge of fertility and vitality in order to generate healthy kids. All three pulses have distinct properties. The *Vata* pulse has a slender, uneven movement similar to that of a snake. The *Pitta* pulse is lively and moves about like a frog hopping. And the *Kapha* pulse is strong, resembling a swan's gliding. The four waves are all included in the conventional radial pulse: (i) Percussion wave, (ii) Tidal wave, (iii) Valley and (iv) Dicrotic wave. This is illustrated in Fig. 2.

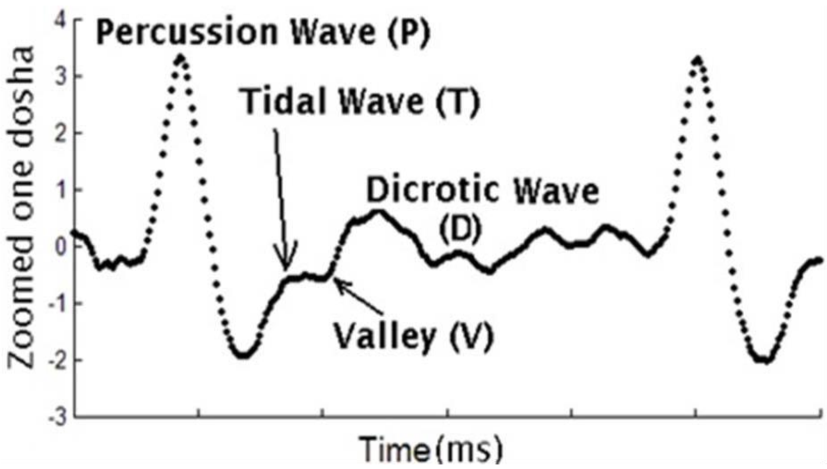

Figure 2 Waveforms in Radial Pulse

The study of the quantitative features of the pulse signal is used to master the translation of subjective data into real format with the help of sensors [1]. This is accomplished by evaluating pulse data in the temporal domain, from which the majority of statistical features useful for health prediction and disease diagnosis are retrieved. Piezo sensors can be used to capture the signal and sends it to be filtered [2].

2. METHODOLOGY AND EXPERIMENTATION

The *Nadi* diagnosis system, which runs on a PC and is also portable, is developed for this purpose. Fig. 3 depicts a diagrammatic representation of the system. The technology includes a microphone that is used to measure *Nadi*, or acoustic waves that can be detected and sensed on the wrist joint, which is the joint between the radius and the carpus. This condenser mic or microphone captures the signal and sends it to be filtered [13].

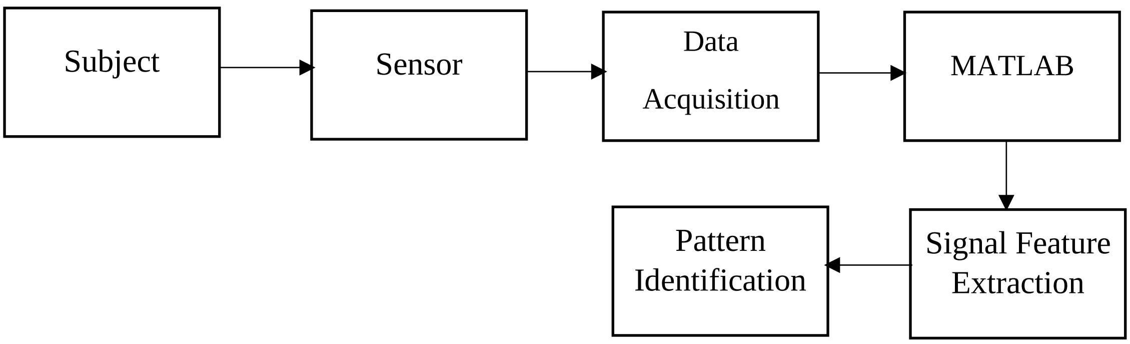

Figure 3 Proposed *Nadi* Diagnosis System

2.1. Pulse Acquisition

The *Nadi* signal, which is detected using the sonic microphone sensor module, is used to diagnose a patient's physiological and emotional state. This paper proposes a novel pulse auscultation system that uses a microphone sensor as a sensing unit and employs high-order filtering to reduce background noise. The sensor's external design is similar to that of a pen. The microphone sensor is positioned at 8.5mm from the tip of the sensor holder, which resembles the structure of a cone. The captured signal is transmitted to the hardware unit, where it is processed using a filter to remove noise and retrieve the desired signal. The final output signal is the artery signal, which is collected and analyzed further. During experimental

validation, this sensor was employed to measure pulse waveforms held in a single position and depths relative to the radial artery on the wrist to meet diagnostic requirements.

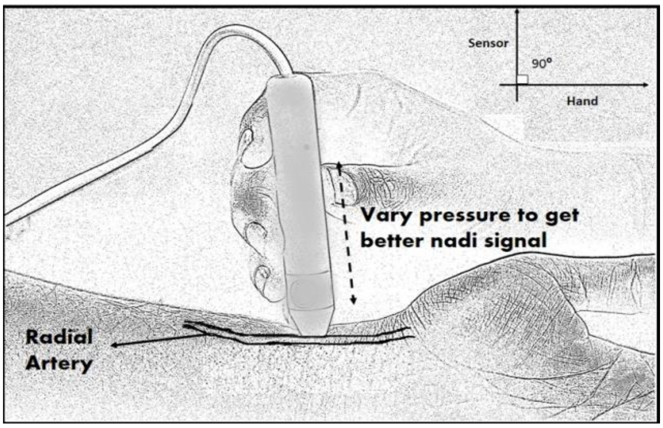

Figure 4 Pulse Auscultation

2.2. Feature Extraction

To classify doshas like *Vata*, *Pitta*, and *Kapha*, statistical properties of the *Nadi* signal [6] are calculated.

2.2.1. Mean

The mean represents the average value determined for all of the coefficients in a *Nadi* signal, indicating the signal's strength. A high mean value *Nadi* signal suggests more strength or force, whereas a low mean value *Nadi* signal indicates less strength or force. The mean of a *Nadi* signal can be calculated as

$$MEAN = \sum\sum \frac{I(m)}{K} \tag{1}$$

where

$I(m)$ is the input signalhaving index m

K is the length of the signal.

2.2.2. Variance

A signal's variance is a measure of its disturbance or changes. In a *Nadi* signal, a region with high variations suggests high variance, whereas a region with low variations indicates low variance. The variance can be computed using the

$$VAR = \frac{\sum_{l=0}^{K-1}(I(l) - MEAN)^2}{K} \tag{2}$$

Where

$I(l)$ is the input signal having *index l*

K is the length of the signal.

2.2.3. Standard Deviation

The square root for the variance can be used to calculate deviation. It can be stated numerically as

$$\sigma = STD = \sqrt{VAR} \tag{3}$$

2.2.4. Energy

The Energy value is between 0 and 1. If a signal contains constant co-efficient values, such as a DC signal, the energy value is 1, but if the co-efficient values are dispersed among different levels, the energy value is decremented. Mathematically, energy may be expressed as

$$ENERGY = \frac{\sum_{l=0}^{K-1} I(l)^2}{K} \tag{4}$$

Where

$I(l)$ is the input signal having index *l*

K is the length of the signa.

2.2.5. Entropy

The information entropy of a *Nadi* signal is a measure of its randomness. Entropy is a mathematical concept that may be expressed as

$$ENTROPY = -\sum_{l=0}^{K-1} P(l) * log_2[P(l)] \tag{5}$$

Where

$P(l)$ probability of occurrance of each sample

K is the length of the signal.

Using MATLAB/Lab View [3] [15] tool, the Acquired *Nadi* signals can be represented as *n*-dimensional symbolic or numerical values called feature vectors in a machine learning and pattern recognition technique, where n indicates the feature quantity. Feature measurements might be numerical, symbolic, or a combination of both. Calculating the aforementioned statistical values for a signal, such as Mean, Standard Deviation, Variance, Energy, Entropy, and so on, and storing these values in a vector, is an example of a numerical feature. The *Nadi* signals can be classified using feature vectors [14]. Feature space is an n-dimensional vector space associated with these feature vectors. This Feature Space allows for the viewing of feature vectors as well as the establishment of relationships between them. Using distance and similarity measurements, we may categorize an unknown sample by comparing it to known examples in Feature Space.

2.3. Classification

Learning/training the machine is the process of calculating statistical features such as Mean, Variance, Standard Deviation, Energy, and Entropy for known *Nadi* signals and storing them in a vector. To categorize the supplied *Nadi* dosha, the characteristics retrieved for query signal are fed into a *K-NN* classifier. Instead of selecting simply a nearby training set sample, the accuracy can be improved by considering nearest neighbours by evaluating a group of close feature vectors [12]. This is known as the K-Nearest Neighbor method. To categorize the unknown sample into the given class, K best matching neighbours are chosen. K might be any number between one and the total number of *Nadi* signals in the training set. The precision of recognition is determined by the K value used. We consider matching neighbours to not matching neighbours in the training set as the value of K grows.
The *K-NN* method works as follows for a given query instance:

$$y_t = \underset{c \epsilon \{c_1, c_2, \ldots\ldots c_m\}}{\arg\ max} \sum_{x_i \epsilon N(x_t, k)} E(y_i, c) \tag{6}$$

Where y_t, is the predicted class for the query instance x_t , c is the class number and m is the class number present in the data. $N(x_t, k)$ Set of k nearest neighbors of x.

$$E(a,b) = \begin{cases} 1 if\ min\ ED \\ 0 if\ max\ ED \end{cases}$$

where

Euclide an distance $ED = \sqrt{\sum_{i=1}^{n}(a_i - b_i)^2}$ between query instance vector a and trained vector b.

3. RESULTS AND DISCUSSIONS

Experiments were conducted to verify that: (i) the extracted characteristic parameters are usable and (ii) the proposed model can identify three doshas, efficiently detecting the patients' *Prakruthi* and *Vikruthi*. In clinical practice, over 5000 pulse signals from 1000 patients were gathered and stored in a pulse signal database. Before being stored in a database, each *Nadi* signal is manually checked by asking *Ayruvedic* practitioners to determine the *Prakruthi* and symptoms of the patient to identify the *Vikruthi*. A total of 5000 signals are considered from various patients, with 1200 *Vata* signals, 2000 *Pitta* signals, and 1800 *Kapha* signals. Out of 5000 pulse signals collected, 4000 signals are utilized for training and 1000 signals are used for testing. To assess system performance, many measures such as the confusion matrix, accuracy, sensitivity, and specificity are calculated.

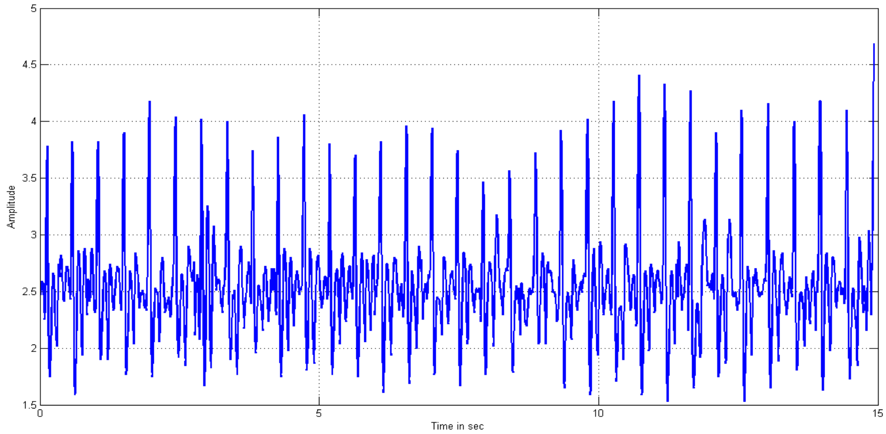

Figure 5 Captured *Vata* signal of a subject

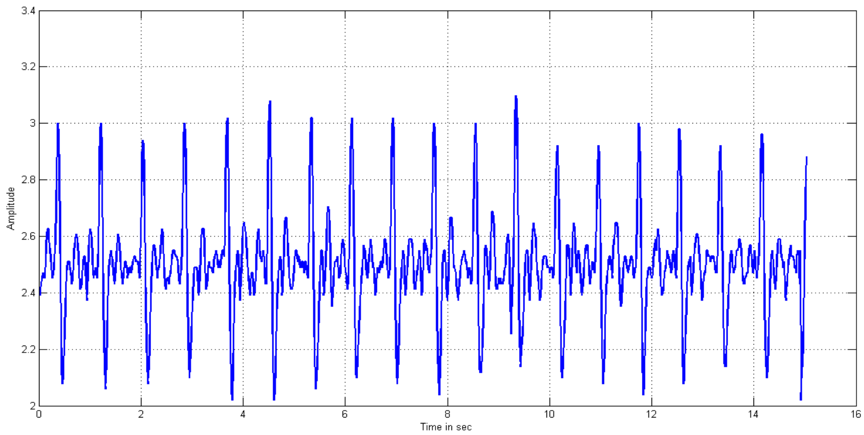

Figure 6 Captured *Pitta* signal of a subject

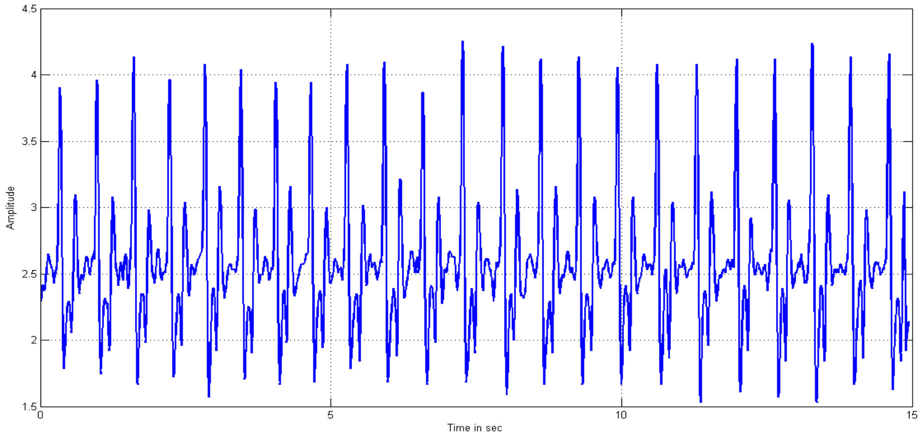

Figure 7 Captured *Kapha* signal of a subject

Table 1 The averaged statistical parameters obtained for 1000 *Nadi* signals for both healthy and unwell individuals.

	Healthy					Unhealthy				
Samples	**Mean**	**Var**	**SD**	**Energy**	**Entropy**	**Mean**	**Var**	**SD**	**Energy**	**Entropy**
Vata	0.644	0.43	0.655	0.34	1.43	0.45	0.35	0.59	0.27	1.28
Pitta	0.8	0.77	0.87	0.55	0.72	0.75	0.81	0.9	0.64	0.89
Kapha	1.21	0.93	0.96	0.89	0.53	1.04	0.98	0.99	0.78	0.47

Fig. 5, Fig. 6, and Fig. 7 depict *Vata*, *Pitta*, and *Kapha Nadi* signals recorded for 15 seconds from unwell people. The number of peaks or heart beats per minute for *Vata* signals is higher, while *Kapha* signals have fewer peaks, and *Pitta* signals have a reasonable number of peaks. The frequency of pulses also differs between the three doshas. The *Vata* pulse has a frequency of 1.32Hz-1.67Hz, whereas the *Pitta* pulse has a frequency of 1.15Hz-1.45Hz and the *Kapha* pulse has a frequency of 0.82Hz-1.24Hz.

The averaged statistical parameters obtained for 1000 *Nadi* signals for both healthy and unwell individuals are shown in Table 1.

Performance Evaluation of the Classifier

In general, a classifier's performance is assessed using variables such as sensitivity, specificity, and classification accuracy, as outlined below.

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} \times 100 \quad (7)$$

$$Sensitivity = \frac{TP}{TP+FP} \quad (8)$$

$$Specificity = \frac{TN}{TN+FN} \quad (9)$$

Where

TP stands for true positive,

TN for true negative,

FP for false positive, and

FN for false negative.

For the positives and negatives in the above equations, these parameters are determined by considering one class in relation to the rest of the classes. For assessing healthy and unhealthy signals, Table 2.0 reveals recognition accuracy, sensitivity, and specificity.

The recognition rate performance is conducted for different values of K by considering 5000 *Nadi* signals which is shown in Fig. 8.It is observed that the recognition rate decreases as the value of K increases.

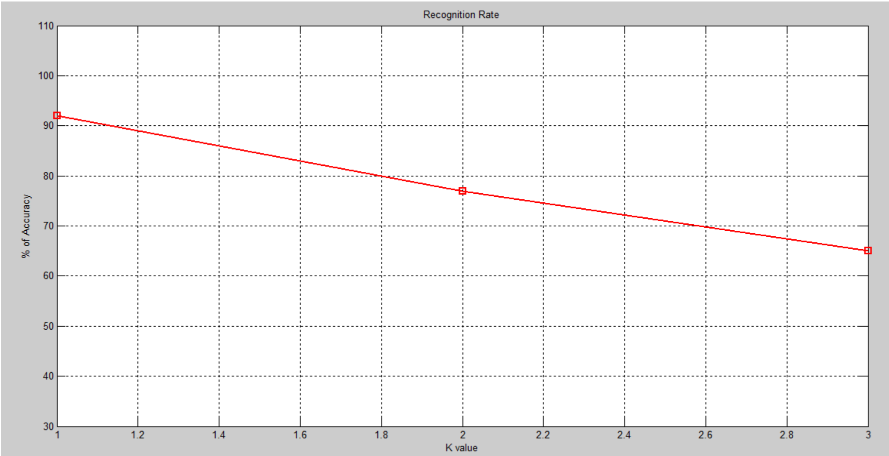

Figure 8 The recognition rate performance is conducted for different values of K.

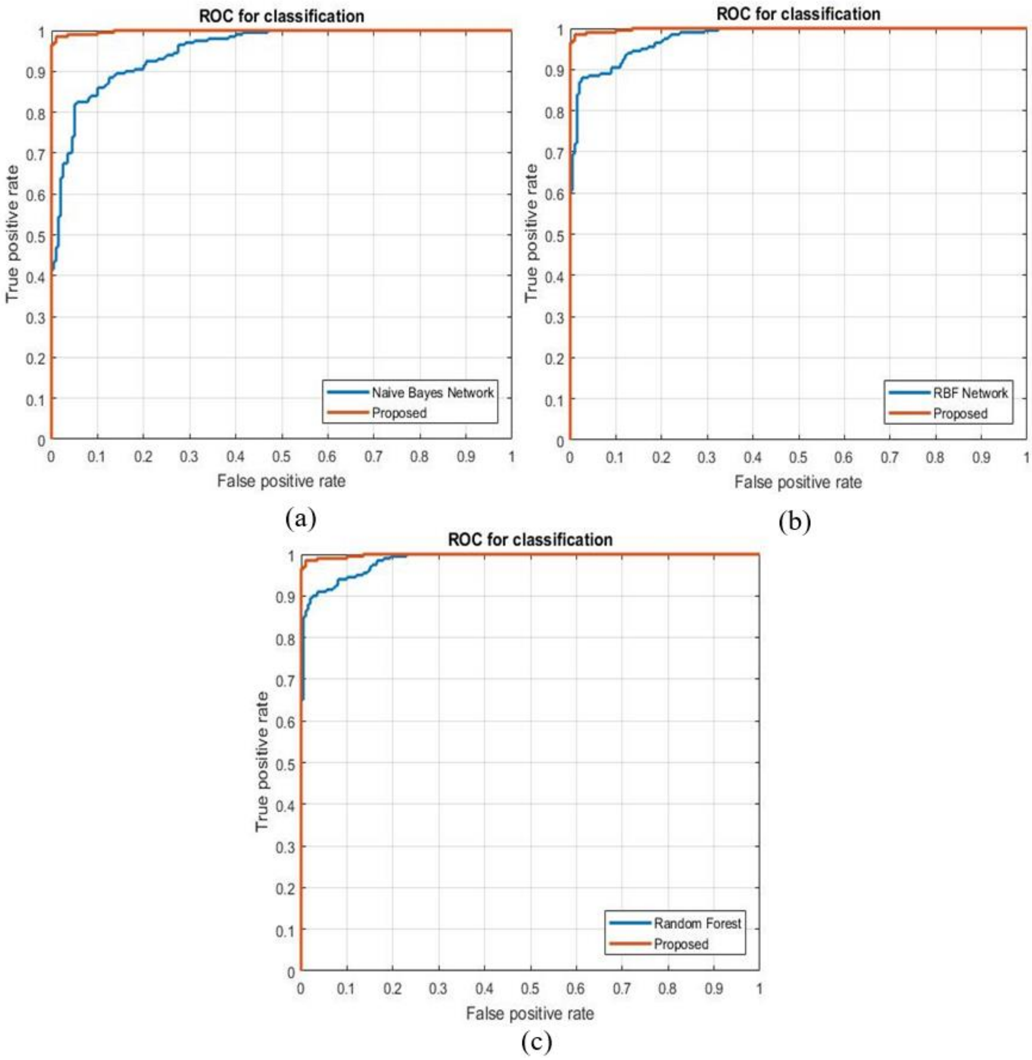

Figure 9 Comparison of Receiver Characteristic Curve (ROC) of the proposed method with (a) Naïve Bayes Network (b) RBF Network (c)Random Forest

The Classification strength of proposed K-NN classifier technique is compared with that of the other classification models such as radial basis function (RBF) [18], naïve Bayes [19] and random forest techniques [20]. The accuracy of the detection is calculated by evaluating performance measures such as sensitivity, specificity, true positive (TP), true negative (TN), false positive (FP) and false negative (FN) as tabulated in Table 3.0. Further, we also computed receiver operating characteristic (ROC) to compare different classifiers. The ROC curves are plotted by keeping false positive rates along X-axis and true positive rates along Y-axis as shown in Fig. 9

Table 2 Reveals recognition accuracy, sensitivity, and specificity for different subjects

	Accuracy	**Sensitivity**	**Specificity**
Healthy	91.4	89.4	92.7
Unhealthy	92.6	91.33	94.95

Table 3 The Classification strength of proposed Classifier technique is compared with that of the other classification models

Classification Model	**Accuracy**	**Sensitivity**	**1-Specificity**
Proposed (KNN)	91.43	89.41	0.0134
RBF Network [18]	90.44	86.13	0.0787
Naïve Bayes [19]	87.92	83.79	0.0581
Random Forest [20]	89.76	79.52	0.0465

4. CONCLUSION

This article proposes a novel and cutting-edge approach to the development of a *Nadi* diagnosis system. The technology has previously been created using a microphone sound sensor. The noise in the signals is reduced by using a hardware filter. The collected *Nadi* signal at a single position identifies three *Ayurveda* doshas: *Vata*, *Pitta*, and *Kapha*. Different statistical features are retrieved for each signal and categorised using the *K-NN* classifier in order to identify these three doshas. Further improvements can be made by creating a portable/wearable and less expensive health monitoring system for all common disorders that can be easily diagnosed.

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